

# USCG R&D Center Conducts Research in Tactical Oil Spill Surveillance Technology

By Gary L. Hover

Tactical oil spill surveillance technology can provide information that helps cleanup forces do a more efficient job. Types of tactical information required include the location(s) of oil within an area of immediate interest, slick thickness, and state of oil weathering. Accurate tactical information can be used to direct oil skimming operations and to help determine what alternative countermeasures, such as dispersing application and in-situ burning, may be appropriate. Ideally, tactical oil spill sensors should be readily available to provide real-time information in a day/night, all-weather operating environment.

Since 1991 the R&D Center has been conducting research in a variety of oil spill surveillance technologies. Two of these technologies, infrared (IR) imaging and microwave radiometry, are of particular interest to the problem of improving the USCG's tactical spill surveillance capabilities. These technologies cover both ends of the "technical risk" spectrum. At one end of this spectrum is proven, commercially-available IR imaging technology. Infrared imagers are already being used to support Coast Guard oil spill response operations and need only be refined to improve their utility in this mission. At the other end of the spectrum is a new device called the frequency scanning microwave radiometer, or FSR. The FSR measures radio-frequency energy from oil-covered water and analyzes this signal to determine how thick the oil layer is. Looking to the future, it is possible that one day these two sensor technologies could be combined into an affordable tactical oil spill surveillance system that provided better information than could either sensor operating alone.

## INFRARED EVALUATIONS

Much like the personal computer industry,

makers of infrared imagers have substantially improved their products in recent years. It is now possible to purchase a wide variety of compact, lightweight portable IR imagers off the shelf. These imagers, which can be used to observe oil spills from almost any aircraft of opportunity, can greatly improve the timeliness and efficiency of Coast Guard oil spill response by making it possible to track oil slicks and direct cleanup operations at night, even if IR-equipped Coast Guard aircraft are unavailable. Under these circumstances, the challenge for the R&D Center was in identifying the specific types of portable IR systems that would best supplement the Coast Guard's limited number of forward-looking infrared (FLIR)-equipped aircraft in the tactical spill surveillance role. Equally important was the need to understand how reliably IR devices can detect oil, to determine what other substances might appear similar to oil in IR images, and to identify sensor design and operator training issues that needed to be addressed.

Two field evaluations conducted by the R&D Center have compared the imaging capabilities of several commercially-available, hand-held IR sensors to those of the Coast Guard's aircraft-installed FLIRs. The first was conducted in May 1993 at a military base in Ontario, Canada. This experiment, hosted by Environment Canada, offered an opportunity for the Coast Guard to test three of its infrared-equipped aircraft and three portable IR systems against known oil slick targets in a specially-constructed outdoor test. The second field test was conducted in November 1994 over the naturally-occurring oil seeps off Santa Barbara, California. During this second field test a Coast Guard helicopter flew over the oil seeps and imaged them with its own installed FLIR system while four hand held IR imagers were operated in shifts from an open side door.

After the May 1993 experiment the Eighth Coast Guard District (New Orleans, Louisiana area)

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purchased a portable IR imager to use and evaluate during actual spill response operations. A very notable spill at which this system was employed was the MORRIS J. BERMAN tank barge grounding off San Juan, Puerto Rico in January 1994. The nighttime image shown in figure 1 depicts oil escaping from the grounded barge, with the oil appearing cooler than sea water in the black is the hot IR image. Pumps running topside on the barge deck appear as hot objects. Since then, use of portable IR imagers for tactical oil spill surveillance has grown considerably within the Coast Guard, and new equipment has been purchased by many Coast Guard districts for this purpose.

Another example of the USCG's use of IR for tactical surveillance is taken from an oil spill that occurred on the Delaware River near Philadelphia, Pennsylvania in July 1994. A USCG HH-60J helicopter with its gimbal-mounted FLIR 2000 system was dispatched to provide night surveillance of the spill. Figure 2, obtained at 0230 local time, shows an

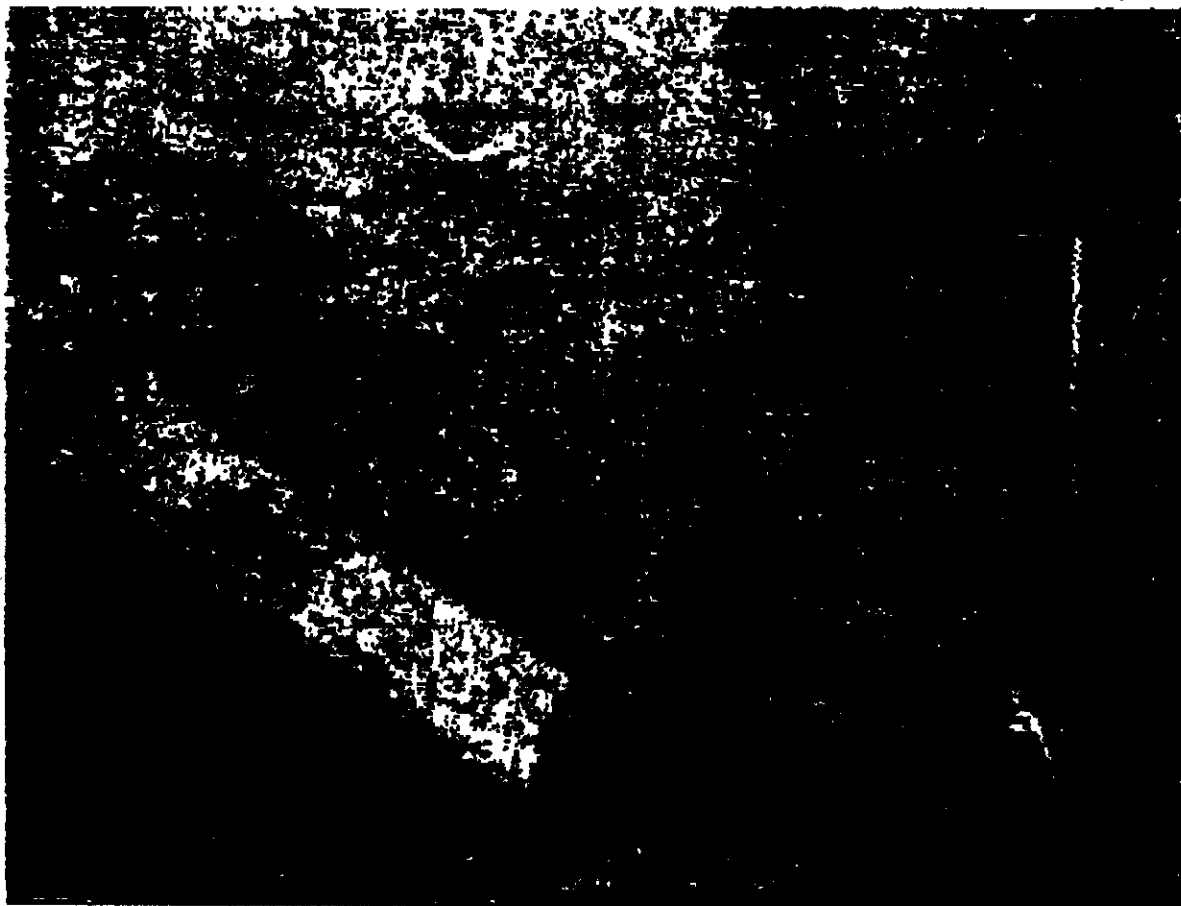
IR view of the leaking tanker vessel KENTUCKY moored at a pier with its associated oil slick flowing down river. Without the aid of the FLIR-equipped helicopter, response units would not have been able to monitor the extent and movement of this spill until after daybreak.

In addition to evaluating the newest portable IR technology, a side benefit of this project has been to develop a better understanding of the oil spill surveillance capabilities already offered by the USCG's existing airborne FLIR resources. Equally important are the operator training issues and imager design factors that were identified and documented as a result of this work.

### FSR DEVELOPMENT AND TESTING

The FSR project explores an innovative concept in passive microwave radiometer design that

Figure 1



Nighttime image of oil escaping from grounded tank barge.

involves scanning a wide frequency band to improve the accuracy of oil slick thickness estimation. This sensor design, referred to as a frequency-scanning radiometer or FSR, also provides data that may prove useful in estimating the degree to which an oil slick has emulsified due to weathering. The design is an improvement over past radiometer systems which observed microwave signals at only one to three fixed frequencies. Whereas, fixed-frequency radiometers are very susceptible to measurement errors, the FSR requires only reasonable accuracy and a straightforward curve fitting procedure to determine the thickness of uniform oil layers. Unlike the portable infrared imagers, however, the FSR concept is unique and represents a completely new instrument design that is not now commercially available.

In 1992 the R&D Center contracted with the Massachusetts Institute of Technology (MIT) Lincoln Laboratory to develop and laboratory test

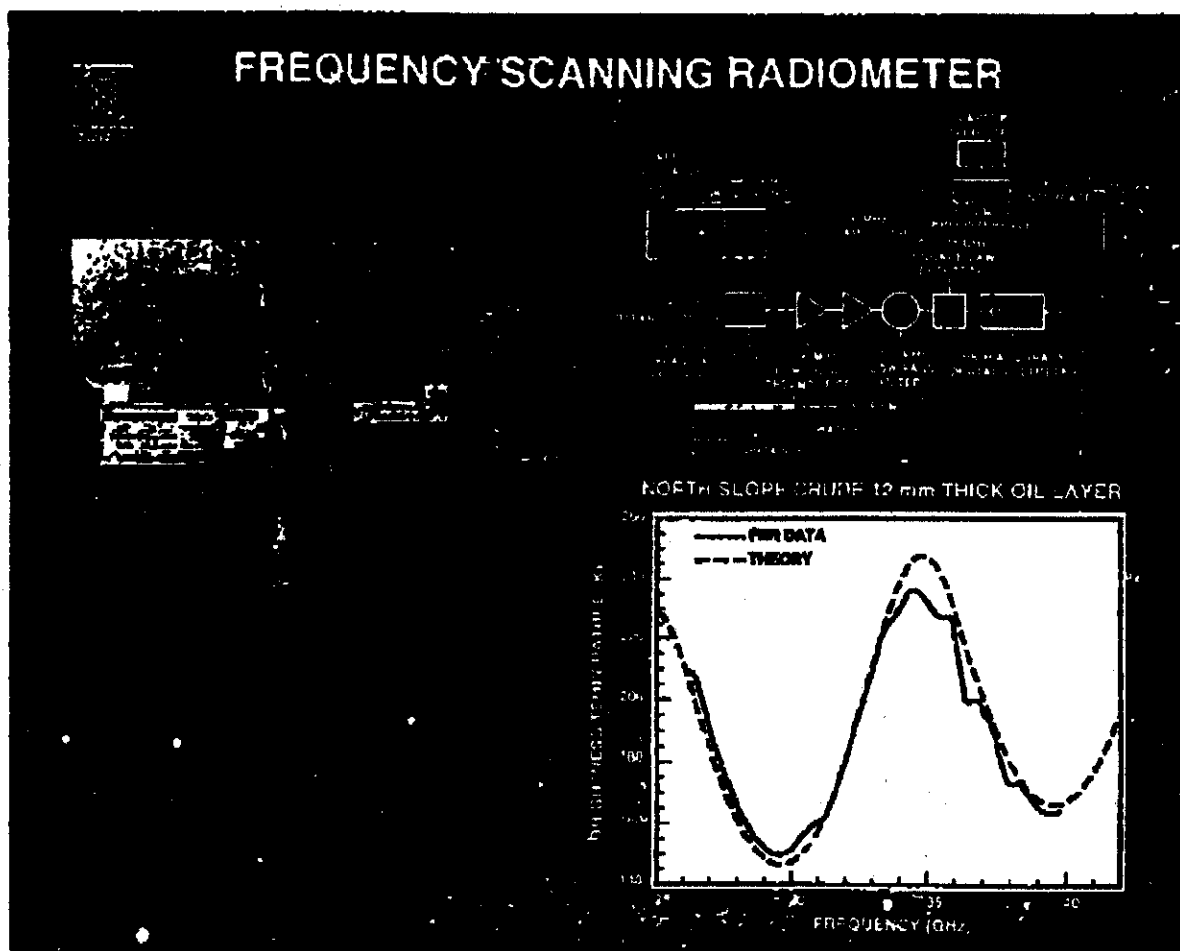
the FSR concept for measuring oil slick thickness. A laboratory prototype FSR operating in the 26 to 40 GHz band was built and initially tested with several types of oil at various uniform layer thickness. Figure 3 shows a photograph of the laboratory prototype FSR along with a schematic diagram for the instrument and a sample data plot. As illustrated in figure 3, these uniform-layer measurements matched very well with theoretical predictions, prompting additional measurements with non-uniform oil layers and water/oil emulsions. Many of the non-uniform oil layer measurements appeared to reflect an average of the layers present within the FSR antenna footprint. As expected, emulsions and non-homogeneous oil layers tended to cause a general rise in brightness temperature across the entire FSR band, providing an indication of weathered oil. The laboratory phase of FSR testing was successful enough to warrant larger-scale measurements in a wave tank.

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Figure 2



*Night IR image of oil slick near TN KENTUCKY on the Delaware River*



*Laboratory prototype FSR with sample data plot*

**Figure 3**

In October 1994, the FSR was ruggedized, repackaged, and brought to the Oil and Hazardous Materials Environmental Test Tank (OHMSETT) facility in New Jersey for a two-week data acquisition experiment. A variety of petroleum products ranging from diesel fuel to crude oil and emulsions were measured at various thickness and simulated sea states. Analysis to the experiment data indicates good agreement with the laboratory results under calm conditions, but improvements will be needed to produce reliable results in the presence of waves. More development and testing will be required to fully determine the operational utility of the FSR concept.

## FUTURE DIRECTIONS

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While IR technology is already proven and commercially available, improvements could be made

to the Coast Guard's existing portable imagers that would make them much easier to use in the dynamic airborne environment. New, uncooled IR detectors are becoming available that can substantially reduce the size, weight, cost and power consumption of portable IR imagers. These should be evaluated by the various operational Coast Guard programs that could benefit from widespread availability of portable night imaging technology. Improved methods of annotating the image data and transmitting it to the user would also be beneficial. Training is needed to provide sensor operators and end-users with the skills required to accurately interpret IR imagery and discriminate false targets from those of genuine mission interest.

### FSR:

An operationally-practical FSR would require much faster data acquisition speed to keep pace with a moving aircraft. A faster instrument has been

designed but has not yet been built or tested. An operational FSR would also likely need a second channel at higher frequencies to more effectively distinguish among oil thickness from a few tenths of a millimeter to 3 mm. The issue of what spatial resolution is required in the oil thickness data is one that requires coordination between the sensor designer and spill response operations personnel.

**Integration:**

Assuming that an operationally-viable FSR can be constructed, how might one be integrated with IR sensors to provide a more robust tactical oil spill surveillance capability? A simple strategy would involve using a grumbled, gyrostabilizer FLIR to guide an FSR-equipped aircraft to oil slick areas of interest. A second IR imager would then provide a strip-map to the end-user which could be annotated

with important mission data and thickness profile information obtained from the FSR and infrared greyscale measurements. This hybrid product would provide response units with a more completed tactical picture than can now be delivered. The challenge is to put the concept into practice!

**ABOUT THE AUTHOR**

Gary Hover has worked on numerous U.S. Coast Guard remote sensing projects in the area of search and rescue, law enforcement, ice reconnaissance and oil spill surveillance since 1979. He presently works as a Senior Research Engineer in the Marine Operations Technology Division at the USCG R&D Center.



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